

Claims

- [c1] An electrophoretic medium comprising a plurality of pigment particles suspended in a suspending fluid, the pigment particles having from about 1 to about 15 per cent by weight of the pigment of a polymer chemically bonded to, or cross-linked around, the pigment particles.
- [c2] An electrophoretic medium according to claim 1 wherein the polymer is cross-linked around the pigment particles.
- [c3] An electrophoretic medium according to claim 1 wherein the polymer is chemically bonded to the pigment particles.
- [c4] An electrophoretic medium according to claim 1 wherein the particles have from about 4 to about 15 per cent by weight of the pigment of the polymer chemically bonded to the pigment particles.
- [c5] An electrophoretic medium according to claim 4 wherein the particles have from about 6 to about 15 per cent by weight of the pigment of the polymer chemically bonded to the pigment particles.
- [c6] An electrophoretic medium according to claim 5 wherein the particles have from about 8 to about 12 per cent by weight of the pigment of the polymer chemically bonded to the pigment particles.
- [c7] An electrophoretic medium according to claim 1 wherein the particles comprise a metal oxide or hydroxide.
- [c8] An electrophoretic medium according to claim 7 wherein the particles comprise titania.
- [c9] An electrophoretic medium according to claim 8 wherein the titania particles have from about 6 to about 15 per cent by weight of the pigment of the polymer chemically bonded to the pigment particles.
- [c10] An electrophoretic medium according to claim 8 wherein the titania particles have from about 8 to about 12 per cent by weight of the pigment of the polymer chemically bonded to the particles.

- [c11] An electrophoretic medium according to claim 1 wherein the particles comprise carbon black.
- [c12] An electrophoretic medium according to claim 11 wherein the carbon black particles have from about 8 to about 12 per cent by weight of the carbon black of the polymer chemically bonded to the particles.
- [c13] An electrophoretic medium according to claim 1 wherein the polymer comprises charged or chargeable groups.
- [c14] An electrophoretic medium according to claim 13 wherein the polymer comprises amino or carboxylic acid groups.
- [c15] An electrophoretic medium according to claim 1 wherein charged or chargeable groups are bonded to the pigment particles separately from the polymer.
- [c16] An electrophoretic medium according to claim 1 wherein the polymer comprises a main chain and a plurality of side chains extending from the main chain, each of the side chains comprising at least about four carbon atoms.
- [c17] An electrophoretic medium according to claim 1 wherein the polymer is formed from any one or more of an acrylate, a methacrylate and a substituted styrene.
- [c18] An electrophoretic medium according to claim 17 wherein the polymer is formed from any one or more of 2-ethylhexyl methacrylate, methyl methacrylate, isobutyl methacrylate, t-butyl methacrylate, lauryl methacrylate, isobornyl methacrylate, 2-ethylhexyl acrylate, t-butyl acrylate, 2,2,3,4,4,4-hexafluorobutyl acrylate and p-chloromethylstyrene.
- [c19] An electrophoretic medium according to claim 1 having two types of particles differing in at least one optical characteristic and having differing electrophoretic mobilities.
- [c20] An electrophoretic medium according to claim 19 wherein both types of particles have from about 1 to about 15 per cent by weight of the pigment of the polymer chemically bonded to, or cross-linked around, the pigment particles.

- [c21] An electrophoretic medium according to claim 19 wherein the two types of particles bear charges of opposite polarity.
- [c22] An electrophoretic medium according to claim 19 wherein the two types of particles bear charges of the same polarity but have different electrophoretic mobilities.
- [c23] An electrophoretic medium according to claim 1 wherein the pigment particles and the fluid are encapsulated in a plurality of capsules.
- [c24] An electrophoretic medium according to claim 23 having two types of particles differing in at least one optical characteristic and having differing electrophoretic mobilities encapsulated within each capsule.
- [c25] An electrophoretic medium according to claim 24 wherein both types of particles have from about 1 to about 15 per cent by weight of the pigment of the polymer chemically bonded to, or cross-linked around, the pigment particles.
- [c26] An electrophoretic medium according to claim 25 wherein the two types of particles comprise titania and carbon black respectively and bear charges of opposite polarity.
- [c27] An electrophoretic medium according to claim 23 wherein the capsules are held within a polymeric binder.
- [c28] An electrophoretic medium according to claim 23 wherein the capsules are non-spherical.
- [c29] An electrophoretic display comprising an electrophoretic medium according to claim 1 and at least one electrode arranged adjacent the medium and capable of applying an electric field to the medium.
- [c30] An electrophoretic display according to claim 29 having two electrodes disposed on opposed sides of the electrophoretic medium, at least one of the electrodes being substantially transparent such that the electrophoretic medium can be viewed through the substantially transparent electrode.

- [c31] An electrophoretic display according to claim 29 wherein the suspending fluid and particles are retained within a plurality of capsules, the capsules being retained within a solid binder, and the electrode being secured to the binder.
- [c32] An electrophoretic medium comprising a plurality of carbon black particles suspended in a suspending fluid, said particles having from about 1 to about 25 per cent by weight of the carbon black of a polymer chemically bonded to, or cross-linked around, the carbon black particles.
- [c33] An electrophoretic medium according to claim 32 wherein the polymer is chemically bonded to the carbon black particles.
- [c34] An electrophoretic medium according to claim 33 wherein the carbon black particles have from about 6 to about 14 per cent by weight of the carbon black of the polymer chemically bonded to the carbon black particles.
- [c35] An electrophoretic medium according to claim 32 wherein the polymer comprises charged or chargeable groups.
- [c36] An electrophoretic medium according to claim 32 wherein charged or chargeable groups are bonded to the carbon particles separately from the polymer.
- [c37] An electrophoretic medium according to claim 32 wherein the polymer comprises a main chain and a plurality of side chains extending from the main chain, each of the side chains comprising at least about four carbon atoms.
- [c38] An electrophoretic medium according to claim 32 wherein the carbon particles and the fluid are encapsulated in a plurality of capsules.
- [c39] An electrophoretic medium according to claim 38 having two types of particles differing in at least one optical characteristic and having differing electrophoretic mobilities encapsulated with each capsule.
- [c40] An electrophoretic medium according to claim 38 wherein the capsules are non-spherical.
- [c41] An electrophoretic display comprising an electrophoretic medium according to

claim 32 and at least one electrode arranged adjacent the medium and capable of applying an electric field to the medium.

[c42] An electrophoretic medium comprising a plurality of pigment particles suspended in a suspending fluid, the pigment particles having a polymer chemically bonded to, or cross-linked around, the pigment particles, the polymer comprising a main chain and a plurality of side chains extending from the main chain, each of the side chains comprising at least about four carbon atoms.

[c43] An electrophoretic medium according to claim 42 wherein each of the side chains comprises at least about six carbon atoms.

[c44] An electrophoretic medium according to claim 42 wherein the polymer is chemically bonded to the pigment particles.

[c45] An electrophoretic medium according to claim 42 wherein the particles have from about 4 to about 15 per cent by weight of the pigment of the polymer chemically bonded to the pigment particles.

[c46] An electrophoretic medium according to claim 45 wherein the particles have from about 6 to about 15 per cent by weight of the pigment of the polymer chemically bonded to the pigment particles.

[c47] An electrophoretic medium according to claim 46 wherein the particles have from about 8 to about 12 per cent by weight of the pigment of the polymer chemically bonded to the pigment particles.

[c48] An electrophoretic medium according to claim 42 wherein the particles comprise a metal oxide or hydroxide.

[c49] An electrophoretic medium according to claim 48 wherein the particles comprise titania.

[c50] An electrophoretic medium according to claim 42 wherein the particles comprise carbon black.

[c51] An electrophoretic medium according to claim 42 wherein the polymer

comprises charged or chargeable groups.

- [c52] An electrophoretic medium according to claim 51 wherein the polymer comprises amino or carboxylic acid groups.
- [c53] An electrophoretic medium according to claim 42 wherein charged or chargeable groups are bonded to the pigment particles separately from the polymer.
- [c54] An electrophoretic medium according to claim 42 wherein the polymer is formed from any one or more of an acrylate, a methacrylate and a substituted styrene.
- [c55] An electrophoretic medium according to claim 54 wherein the polymer is formed from any one or more of 2-ethylhexyl methacrylate, isobutyl methacrylate, t-butyl methacrylate, lauryl methacrylate, isobornyl methacrylate, 2-ethylhexyl acrylate, t-butyl acrylate, 2,2,3,4,4,4-hexafluorobutyl acrylate and p-chloromethylstyrene.
- [c56] An electrophoretic medium according to claim 42 having two types of particles differing in at least one optical characteristic and having differing electrophoretic mobilities.
- [c57] An electrophoretic medium according to claim 56 wherein both types of particles have a polymer chemically bonded to, or cross-linked around, the pigment particles, the polymer comprising a main chain and a plurality of side chains extending from the main chain, each of the side chains comprising at least about four carbon atoms.
- [c58] An electrophoretic medium according to claim 56 wherein the two types of particles bear charges of opposite polarity.
- [c59] An electrophoretic medium according to claim 56 wherein the two types of particles bear charges of the same polarity but have different electrophoretic mobilities.
- [c60] An electrophoretic medium according to claim 42 wherein the pigment particles

and the fluid are encapsulated in a plurality of capsules.

- [c61] An electrophoretic medium according to claim 60 having two types of particles differing in at least one optical characteristic and having differing electrophoretic mobilities encapsulated within each capsule.
- [c62] An electrophoretic medium according to claim 61 wherein both types of particles have a polymer chemically bonded to, or cross-linked around, the pigment particles, the polymer comprising a main chain and a plurality of side chains extending from the main chain, each of the side chains comprising at least about four carbon atoms.
- [c63] An electrophoretic medium according to claim 62 wherein the two types of particles comprise titania and carbon black respectively and bear charges of opposite polarity.
- [c64] An electrophoretic medium according to claim 60 wherein the capsules are held within a polymeric binder.
- [c65] An electrophoretic medium according to claim 60 wherein the capsules are non-spherical.
- [c66] An electrophoretic display comprising an electrophoretic medium according to claim 42 and at least one electrode arranged adjacent the medium and capable of applying an electric field to the medium.
- [c67] An electrophoretic display according to claim 66 having two electrodes disposed on opposed sides of the electrophoretic medium, at least one of the electrodes being substantially transparent such that the electrophoretic medium can be viewed through the substantially transparent electrode.
- [c68] An electrophoretic display according to claim 66 wherein the suspending fluid and particles are retained within a plurality of capsules, the capsules being retained within a solid binder, and the electrode being secured to the binder.
- [c69] A two-phase electrophoretic medium comprising a continuous phase and a discontinuous phase, the discontinuous phase comprising a plurality of

droplets, each of which comprises a suspending fluid and at least one pigment particle disposed within the suspending fluid and capable of moving through the fluid upon application of an electric field to the electrophoretic medium, the continuous phase surrounding and encapsulating the discontinuous phase, the pigment particle comprising a polymer chemically bonded to, or cross-linked around, the pigment particle.

- [c70] An electrophoretic medium according to claim 69 wherein the discontinuous phase comprises at least about 40 per cent by volume of the electrophoretic medium.
- [c71] An electrophoretic medium according to claim 70 wherein the discontinuous phase comprises from about 50 to about 80 per cent by volume of the electrophoretic medium.
- [c72] A electrophoretic medium according to claim 69 wherein the continuous phase comprises a radiation-cured material.
- [c73] An electrophoretic medium according to claim 69 wherein the continuous phase comprises gelatin.
- [c74] An electrophoretic medium according to claim 73 wherein the gelatin comprises about 5 percent to about 15 percent by weight of the electrophoretic medium.
- [c75] An electrophoretic medium according to claim 69 wherein the polymer is cross-linked around the pigment particles.
- [c76] An electrophoretic medium according to claim 69 wherein the polymer is chemically bonded to the pigment particles.
- [c77] An electrophoretic medium according to claim 69 wherein the particles have from about 1 to about 15 per cent by weight of the pigment of the polymer chemically bonded to the pigment particles.
- [c78] An electrophoretic medium according to claim 77 wherein the particles have from about 4 to about 15 per cent by weight of the pigment of the polymer chemically bonded to the pigment particles.

- [c79] An electrophoretic medium according to claim 78 wherein the particles have from about 8 to about 12 per cent by weight of the pigment of the polymer chemically bonded to the pigment particles.
- [c80] An electrophoretic medium according to claim 69 wherein the particles comprise a metal oxide or hydroxide.
- [c81] An electrophoretic medium according to claim 80 wherein the particles comprise titania.
- [c82] An electrophoretic medium according to claim 81 wherein the titania particles have from about 6 to about 15 per cent by weight of the pigment of the polymer chemically bonded to the pigment particles.
- [c83] An electrophoretic medium according to claim 82 wherein the titania particles have from about 8 to about 12 per cent by weight of the pigment of the polymer chemically bonded to the particles.
- [c84] An electrophoretic medium according to claim 69 wherein the particles comprise carbon black.
- [c85] An electrophoretic medium according to claim 84 wherein the carbon black particles have from about 1 to about 25 per cent by weight of the carbon black of a polymer chemically bonded to the particles.
- [c86] An electrophoretic medium according to claim 85 wherein the carbon black particles have from about 8 to about 12 per cent by weight of the carbon black of the polymer chemically bonded to the particles.
- [c87] An electrophoretic medium according to claim 69 wherein the polymer comprises charged or chargeable groups.
- [c88] An electrophoretic medium according to claim 87 wherein the polymer comprises amino or carboxylic acid groups.
- [c89] An electrophoretic medium according to claim 69 wherein charged or chargeable groups are bonded to the pigment particles separately from the polymer.

- [c90] An electrophoretic medium according to claim 69 wherein the polymer comprises a main chain and a plurality of side chains extending from the main chain, each of the side chains comprising at least about four carbon atoms.
- [c91] An electrophoretic medium according to claim 69 wherein the polymer is formed from any one or more of an acrylate, a methacrylate and a substituted styrene.
- [c92] An electrophoretic medium according to claim 91 wherein the polymer is formed from any one or more of 2-ethylhexyl methacrylate, methyl methacrylate, isobutyl methacrylate, t-butyl methacrylate, lauryl methacrylate, isobornyl methacrylate, 2-ethylhexyl acrylate, t-butyl acrylate, 2,2,3,4,4,4-hexafluorobutyl acrylate and p-chloromethylstyrene.
- [c93] An electrophoretic medium according to claim 69 having two types of particles differing in at least one optical characteristic and having differing electrophoretic mobilities.
- [c94] An electrophoretic medium according to claim 93 wherein both types of particles have from about 1 to about 15 per cent by weight of the pigment of the polymer chemically bonded to, or cross-linked around, the pigment particles.
- [c95] An electrophoretic medium according to claim 93 wherein the two types of particles bear charges of opposite polarity.
- [c96] An electrophoretic medium according to claim 93 wherein the two types of particles bear charges of the same polarity but have different electrophoretic mobilities.
- [c97] An electrophoretic medium according to claim 93 wherein the two types of particles comprise titania and carbon black respectively and bear charges of opposite polarity.
- [c98] An electrophoretic medium according to claim 69 wherein the droplets are non-spherical.

- [c99] An electrophoretic display comprising an electrophoretic medium according to claim 69 and at least one electrode arranged adjacent the medium and capable of applying an electric field to the medium.
- [c100] An electrophoretic display according to claim 69 having two electrodes disposed on opposed sides of the electrophoretic medium, at least one of the electrodes being substantially transparent such that the electrophoretic medium can be viewed through the substantially transparent electrode.
- [c101] A pigment particle for use in an electrophoretic medium, the pigment particle having a polymer chemically bonded to, or cross-linked around, the pigment particle, the pigment particle also having a charged or chargeable group bonded to the pigment particle separately from the polymer.
- [c102] A pigment particle according to claim 101 wherein said polymer is essentially free from charged or chargeable groups.
- [c103] A pigment particle according to claim 101 wherein the polymer is chemically bonded to the pigment particle.
- [c104] An electrophoretic medium comprising at least one particle according to claim 100 suspended in a suspending fluid.
- [c105] An electrophoretic medium according to claim 104 wherein the at least one particle and the suspending fluid are encapsulated within a capsule.
- [c106] An electrophoretic display comprising an electrophoretic medium according to claim 103 and at least one electrode arranged adjacent the medium and capable of applying an electric field to the medium.
- [c107] A process for producing a polymer-coated pigment particle, which process comprises:
- (a) reacting the particle with a reagent having a functional group capable of reacting with, and bonding to, the particle, and also having a polymerizable or polymerization-initiating group, thereby causing the functional group to react with the particle surface and attach the polymerizable group thereto; and
 - (b) reacting the product of step (a) with at least one monomer or oligomer under

conditions effective to cause reaction between the polymerizable or polymerization-initiating group on the particle and the at least one monomer or oligomer, thereby causing the formation of polymer bonded to the particle.

[c108] A process according to claim 107 wherein, in step (a) the polymerizable group is bonded to the particle surface via an ionic bond.

[c109] A process according to claim 108 wherein the bifunctional reagent used in step (a) comprises a silane coupling group.

[c110] A process according to claim 108 wherein the bifunctional reagent used in step (a) comprises a trialkoxysilane coupling group.

[c111] A process according to claim 108 wherein step (a) comprises:
(a1) reacting the particle with a reagent having a first functional group capable of reacting with, and bonding to, the particle and a second functional group capable of reacting to form an ionic bond, thereby causing the first functional group to react with the particle surface and attach the second functional group thereto; and
(a2) reacting the product of step (a1) with a second reagent having a polymerizable group and a third functional group capable of reacting with the second functional group to form the ionic bond, thereby causing the second and third functional groups to react together to form the ionic bond, and thereby attaching the polymerizable group to the particle surface via this ionic bond.

[c112] A process according to claim 111 wherein the second and third functional groups comprise an acidic and a basic group.

[c113] A process according to claim 112 wherein the second and third functional groups comprise an ammonium group and a sulfonic acid group.

[c114] A process according to claim 107 wherein, in step (a) the polymerizable group is bonded to the particle surface via a covalent bond.

[c115] A process according to claim 114 wherein the reagent used in step (a) comprises a silane coupling group and an ethylenically unsaturated group.

- [c116] A process according to claim 115 wherein the reagent used in step (a) comprises a trialkoxysilane coupling group.
- [c117] A process according to claim 107 wherein, in step (a) there is attached to the pigment particle a group which provides an initiating site for atom transfer radical polymerization, and in step (b) the product of step (a) is treated with an atom transfer radical polymerizable monomer to form the polymer.
- [c118] A process according to claim 117 wherein the initiating site comprises a benzylic halogen atom.
- [c119] A process according to claim 117 wherein step (b) is carried out by treating the product of step (a) with a first atom transfer radical polymerizable monomer under conditions effective to cause polymerization of this monomer on to the particle, stopping this first polymerization, and thereafter treating the particle with a second atom transfer radical polymerizable monomer under conditions effective to cause polymerization of this monomer on to the particle, thereby forming a block copolymer of the two monomers on the particle.
- [c120] A process according to claim 107 wherein, in step (a) a polymerizable group is attached to the particle, and in step (b) the product of step (a) is contacted with at least one monomer or oligomer under conditions effective to cause polymerization of the monomer or oligomer with the polymerizable group on the polymer, thereby causing formation of the polymer on the particle.
- [c121] A process according to claim 120 wherein the at least one monomer or oligomer used in step (b) comprises at least one monomer or oligomer having a chain of at least about four carbon atoms attached to a polymerizable group, where by the polymer formed on the particles comprises a main chain and a plurality of side chains extending from the main chain, each of the side chains comprising at least about four carbon atoms.
- [c122] A process according to claim 120 wherein the at least one monomer or oligomer used in step (b) comprises at least one monomer or oligomer comprising a group capable of initiating polymerization but which essentially does not initiate such polymerization under the conditions used in step (b), and

following step (b) the polymer-bearing particle is contacted with at least one monomer or oligomer under conditions which cause the group capable of initiating polymerization to initiate polymerization of the at least one monomer or oligomer, thereby causing the formation of a branched-chain polymer on the particle.

[c123] A process according to claim 122 wherein the group capable of initiating polymerization is a group capable of initiating atom transfer radical polymerization.

[c124] A process according to claim 122 wherein the group capable of initiating polymerization is a group capable of initiating stable free radical polymerization.

[c125] A process according to claim 107 further comprising depositing at least one of silica and alumina on the pigment particle prior to step (a).

[c126] A process according to claim 125 wherein silica is deposited on the particle prior to step (a), the deposition being effected such that substantially the entire surface of the pigment particle is covered by the silica.

[c127] A process according to claim 107 further comprising dispersing the polymer-coated pigment particle into a suspending fluid to form an electrophoretic medium.

[c128] A process for coating a pigment particles with silica, the process comprising:
dispersing the pigment particles in a solution of a soluble silicate at a pH above about 8 and a temperature above about 60 ° C;
adding to the dispersion of the pigment particles both a solution of an acid and a solution of a soluble silicate while maintaining the temperature of the dispersion above about 60 ° C, thereby causing deposition of silica on to the particles; and
lowering the pH of the dispersion below about 4, and thereafter separating the silica-coated particles from the liquid.

[c129] A process according to claim 128 wherein the dispersion of the pigment

particles is maintained at a temperature in the range of about 80 to about 100 ° C as the solution of the acid and the solution of the soluble silicate are added thereto.

[c130] A process according to claim 128 wherein the soluble silicate is sodium silicate.

[c131] A process according to claim 128 wherein the acid is sulfuric acid.

[c132] A process according to claim 128 wherein the reaction mixture is maintained substantially free from aluminum.

[c133] A process according to claim 128 further comprising redispersing the separated silica-coated particles in an aqueous alcohol.

[c134] An electrophoretic display comprising:

- a) an arrangement of microscopic containers, wherein each container comprises a dielectric fluid and a suspension of particles having attached at least one organic group, wherein said organic group includes at least one ionic group, ionizable group, or both, wherein said fluid and said particles contrast visually;
- b) first and second electrodes wherein said arrangement is located between said electrodes and wherein at least one of the electrodes is substantially visually transparent; and
- c) means for creating a potential difference between the two electrodes, wherein said potential difference causes said particles to migrate towards one of the electrodes.

[c135] A non-emissive display system comprising:

- a) at least one display element located between two electrodes wherein the display element is visually responsive to a potential difference between the electrodes; and
- b) a display piezoelectric element connected to the electrodes wherein deformation of the piezoelectric element produces the potential difference; wherein said display element comprises an arrangement of microscopic containers, wherein each container comprises a dielectric fluid and a suspension of particles having attached at least one organic group, wherein said organic group includes at least one ionic, ionizable group, or both, wherein said fluid

and said particles contrast visually.

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